Changing the stability conditions in a back squat: the effect on maximum load lifted and erector spinae muscle activity

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Running head: Effects of various stability conditions in back squat

Abstract

The aim of this study was to identify how changes in the stability conditions of a back squat affect maximal loads lifted and erector spinae muscle activity. Fourteen male participants performed a Smith Machine squat (SM), the most stable condition, a Barbell back squat (BB) and Tendo-Destabilising Bar squat (TBB), the least stable condition. A one repetition max (1-RM) was established in each squat condition, before electromyography (EMG) activity of the erector spinae was measured at 85% of 1-RM. Results indicated that the SM squat 1-RM load was significantly ($p = 0.006$) greater (10.9%) than BB squat, but no greater than TBB squat. EMG results indicated significantly greater ($p < 0.05$) muscle activation in the TBB condition compared to other conditions. The BB squat produced significantly greater ($p = 0.036$) EMG activity compared to the SM squat. A greater stability challenge applied to the torso seems to increase muscle activation. The maximum loads lifted in the most stable and unstable squats were similar. However, the lift with greater stability challenge required greatest muscle activation. The implications of this study may be important for training programmes; coaches wishing to challenge trunk stability, while their athletes lift maximal loads designed to increase strength.

Key Words: electromyography, *torso instability, squat performance, muscle activity*

Word Count 200

Introduction

Resistance training has long been considered the most effective way of increasing muscular strength for the human muscular skeletal system in general (Peterson, Rhea, & Alvar, 2005). It has also been proposed that 'functional training', where natural movements are executed in multiple planes, is superior to isolation of individual limb movements (Norwood, Anderson, Gaetz, & Twist, 2007). This is exemplified by the popularity of the back squat as a way of loading the lower extremities in flexion/extension patterns, common to many sporting actions. In addition, the back squat places a demand on the torso musculature and in particular the erector spinae to maintain a neutral spine (Schwanbeck, Chilibeck, & Binsted, 2009). Consequently, the load applied to the torso causes a stability challenge for the athlete to control.

Increasing the stability challenge for athletes has been popularised by increasing the instability of specific movements in order to promote trunk muscle activation in whole body actions. This has involved performing exercises on unstable support surfaces such as Swiss Balls or Bosu Balls (Anderson & Behm, 2004; Drake et al., 2006; Vera-Garcia, Elvira, Brown, & McGill, 2007) in the belief that this will increase neuromuscular recruitment (Lehman, 2007). Although studies (Anderson, & Behm, 2005; Norwood et al., 2007) have found that the use of unstable surfaces is linked to increased neuromuscular activity, these findings could be misleading. Anderson and Behm (2005) and Norwood et al. (2007) used the same load within their stable and unstable conditions, despite the maximal loads lifted in unstable conditions being reported to be substantially less than the same actions in stable conditions (McBride, Larkin, Doyne, Haines, &

Kirby, 2010). Indeed, the maximum force agonistic muscles can produce in unstable exercises has been reported to be reduced to less than 70% of the force produced in comparable stable activities (Drake, Fischer, Brown, & Callaghan, 2006; Drinkwater, Pritchett, & Behm, 2007; Santana, Vera-Garcia, & McGill, 2007). Therefore, if studies on unstable actions are using a higher percentage of one repetition max (1-RM), then it is unsurprising that greater electromyography (EMG) activity is suggested to be linked to exercises performed on unstable surfaces. Moreover, when research has compared the same relative loads, an increase in neuromuscular activity in the stable rather than the unstable condition has been established (Hamlyn, Behm, & Young, 2007; McBride et al., 2010). The validity of exercising on unstable surfaces can also be criticised. Movement in real sports situations often involves athletes having a stable surface (the ground) to apply force to, while overcoming an unstable resistance such as an opponent or an external load (Kohler et al., 2010). In these situations greater trunk stability is required and simply using an unstable platform has limited value within ground-based sports.

A more valid resistance training modality could be the use of lifting unstable loads. This type of training, where the mass shifts randomly during the lift action, has become popular in many training facilities (Behm & Colado, 2012). This is exemplified by the use of water-filled logs (Langford, McCurdy, Ernest, Doscher, & Walters, 2007) within training regimes. These lifts are purported to simulate more functionally valid conditioning regimes for athletes whose sport requires dealing with unstable loads. Past work would suggest that lifting an unstable load can lead to greater EMG output in the trunk musculature (Lee, & Lee, 2002; Van Dieen, Kingma, & Van der Bug, 2001) and an increase in force (Van Dieen, Dekkers, Joris, Groen, Toussaint, & Meijer, 2001) compared to stable loads of the same mass. However, these lifts have not been examined in any depth within the scientific literature. The loads examined have been light (e.g. 10 kg [Van Dieen et al., 2001] or 18 kg [Lee & Lee, 2002]) which do not represent loads typically used by athletes to develop strength. To the authors' knowledge, no study has explored the back squat while lifting an unstable load when a suitable strength training intensity (85% or higher of 1-RM) is applied.

Therefore, the aim of this study was to identify how changes in the stability conditions applied to a barbell during a back squat affect maximal load lifted and erector spinae muscle activity. It was hypothesised that less stable scenarios would induce greater EMG activity, while decreasing the maximal load lifted.

Methods

Participants

Fourteen healthy males with a minimum free weight squat experience of one year and no history of back pain (age = 21.7 ± 2.6 years, height = 1.79 ± 0.07 m and body mass = 83.2 ± 14.1 kg, 1-RM back squat = 123.5 ±35.5 kg, relative strength = 1.56 ± 0.43 kg lifted/kg of body mass) volunteered for this study. Participants were collegiate games players who trained or played a minimum of three times per week and took part in at least one squat-based training session per week. Participants were tested during their transition phase before pre-season training commenced. Procedures were approved by the University of Bedfordshire's Institute of Sport and Physical Activity Research

Committee for Ethics in accordance with the Helsinki Declaration of 1983. Before written consent was obtained, participants completed a health screen and were provided with written and oral information regarding the experimental protocol and the possible risks of participation. Participants were required not to consume alcohol or perform any physical activity in the 24 hours prior to each testing session. Participants did not consume food or any caffeine products for four hours prior to testing. Participants were instructed to continue their regular training throughout the experimental period; this was monitored via a training diary and only maintenance dosages of exercise stimulus were involved. Power calculations (G*Power3, Erdfelder, Faul, & Buchner, 1996) using participant numbers (n=14) and the alpha level achieved during main effect calculations, found a 1-RM statistical power of 0.944 and EMG power of 0.984.

Experimental Design

Three different squat techniques were explored in this randomized, counter-balanced repeated measures study. Three different 1-RM lifts were performed, categorised by level of stability. The most stable condition was the Smith Machine (Pullum, Luton, UK) squat, where the bar lifted was stabilized by two parallel tracks allowing movement in only the sagittal plane. The mid-stability condition was the Barbell (Pullum, Luton, UK) squat, where the bar is able to freely move in all three planes. The least stable condition was the Tendo-Destabilizing Bar (Tendo Sports Machine, Basingstoke, UK) squat. The Tendo system uses a normal barbell, with a 30-kg exercise load hung below the bar on two 3.5 kg springs. It should be noted that while the hung load in the Tendo system can be changed, 30-kg is the maximum mass recommended by the manufacturer. A load of

30-kg was chosen as it was felt that this would have the largest impact on lift performance and EMG, establishing if the system had any potential benefit to athletes. The system swings in an anterior and posterior direction, while oscillating vertically during the lift, creating a stability challenge to the torso musculature (see Figure 1). The EMG activity of the erector spinae was recorded at 85% of the participant's 1-RM, individually calculated from the separate 1-RM test for each squat conditions examined.

Figure 1 about here

Procedures

Participants were required to perform a high bar back squat in each of the test conditions which involved positioning of the feet shoulder width apart, with the barbell across the shoulders resting on the trapezius and slightly above the posterior aspect of the deltoids. The squat consisted of hip and knee flexions until the top of the thighs were parallel to the floor, followed by an immediate extension of the hips and knees. Participants kept their backs in a neutral curve, with their heels on the floor and knees in line with their toes throughout each lift (Gullett, Tillman, Gutierrez, & Chow, 2009). All squat actions were videoed to ensure required technique was maintained, any deviation from this resulted in that particular squat being removed from the data set. Each squat's timing was standardised using a metronome (MIE Medical Research Ltd, Leeds, UK) set at 40 beats/min, with participants instructed to lift at the same tempo for the downward and upward phase of the squat to prevent bouncing at the bottom and top of the squat action, which could cause an increase in the oscillation of the Tendo device. Squat depth was established during a familiarisation session, with a gravity dependent goniometer (MIE Medical Research Ltd, Leeds, UK) used to indicate when the top of the thighs were parallel to the floor. This position was recorded and standardised in all the following experimental sessions. Appropriate squat depth was achieved when participants touched their ischial tuberosities on a bar, held by two clamp stands, at the bottom of each squat. Foot position was standardised as shoulder width, with the amount of hip external rotation self selected. This stance position was recorded during the familiarisation session and tape markers placed on the floor to keep the foot position standard. Foot position was constant within the three squat derivatives examined, however it is acknowledged that the Smith Machine squat torso position was more upright than the other two squats lifts, due to the fixed nature of the bar within the Smith Machine.

Familiarisation and 1 Repetition Maximum Protocol (1-RM)

Independent 1-RM test sessions were conducted in a randomised counter balanced fashion for each of the three back squat interventions utilised in this study. A ten-minute warm-up on a cycle ergometer (Monark Ergomedic, Monark Exercise, 874E, Vansbro, Sweden) performed at 100 W was completed before foot position and squat depth were established. Participants then performed ten squats using only the bar at the required metronome rate. When this rate could be reproduced, a 1-RM test was performed, to establish the maximum load each participant could lift for each squat type. This involved increasing load incrementally, until failure to perform a squat with good form to a parallel position was established. Three minutes seated rest was enforced between each squat attempt. The heaviest load lifted correctly was used as a measure of 1-RM

(Baechle, Earle, & Wathen, 2003). The three test sessions were performed seven days apart, to prevent the impact of fatigue on test scores, and at the same time of day to avoid any diurnal variations. A qualified strength and conditioning coach supervised this and all subsequent exercise sessions. The 1-RM protocol was used for the Smith Machine squat, the barbell squat and the destabilizing bar squat.

Experimental Protocol

Participants performed three repetitions of each squat type in a random order, using 85% of the 1-RM achieved in each of the three squat 1-RM tests. A five minute warm-up at 100 W was performed on a cycle ergometer, followed by eight squats with just the bar to establish the correct movement pattern and test velocity. Three repetitions were then performed at 50% of 1-RM, followed by three minutes seated rest, before three repetitions at 85% of 1-RM were performed. The same warm-up was performed prior to each squat type. Seventy two hours rest, where no resistance exercise was performed, was enforced between the three test sessions.

Electomyographical Analysis

EMG recordings were collected for each squat type and for all three repetitions performed at 85% of 1-RM. Participants were fitted with 40 mm silver/silver chloride electromyographic electrodes (EMG electrodes, Cardiocare Limited, Romford, UK), after the skin was shaved and cleaned with an alcohol swab to minimise electrical impedance (Hamlyn et al., 2007). Electrodes were attached onto the skin on the dominant and non-dominant side of the erector spinae longissimus, positioned on the midpoint of the muscle belly and two fingers width lateral from the lumbar vertebrae L1 (SENIAM, http://seniam.org/), with an inter-electrode distance of 2 cm, aligned parallel to the direction of the underlying fibres (Clarys & Cabri, 1993). A reference electrode was positioned on the cervical vertebrae C7 (Seniam, 1997). Electrodes were attached with participants lying prone, with their lumbar vertebral columns slightly flexed (SENIAM, http://seniam.org/).

EMG activity was recorded at a sampling frequency of 2,000 Hz, with the high-pass filter set at 20 Hz and the low-pass filter at 500 Hz and a mains notch filter utilised (Enoka, 2002). The EMG signals were recorded using a Powerlab isolated amplifier (Powerlab AD Instruments 4/25T, AD Instruments, Chalgrove, UK). The data were analysed using a computer program (Chart version 5.4.1, AD instruments, Chalgrove, UK). The raw EMG signal was processed by full wave rectification, integrated and averaged (average rectified value) for each squat repetition within each test condition.

EMG signals were normalized by measuring the average rectified value of a maximal voluntary isometric contraction (MVC) performed after the main squat test (Burden & Bartlett, 1999; Fletcher, 2010). MVCs were performed after the main test battery to limit any possible effects linked to post-activation potentiation (PAP) which could be caused by maximal contractions and could result in either increased performance, by stimulating the nervous system, or decreased performance, by causing a level of fatigue (Chiu, Schilling, Johnson, & Weiss, 2004). In order to prevent the squat repetitions from affecting the MVC value due to fatigue (Burden, Trew, Baltzopoulos, 2003; DeLuca, 1997), a five-minute seated rest was enforced prior to MVC measurement. It was assumed that any fatigue from the squats performed would be the same for each squat condition, therefore if the MVC's were decreased by being performed post squat test this would be similar for each test condition. The MVC involved participants performing an isometric squat against an immovable barbell at a knee angle of 135° for three seconds, (Burden et al., 2003; DeLuca, 1997), with foot position standardised to mimic that of all three squat conditions. MVC's were performed three times with two-minute rest between contractions (DeLuca, 1997). This measurement represented the EMG activation of erector spinae at an MVC relative to the squatting action only. Greater EMG output may be possible by isolating spinal extension through dynamometry, but would not represent the potential activation during a squat movement. This activation data was used for comparisons between the EMG values for each squat and for the dominant and non-dominant erector spinae longissimus musculature. This process allowed the calculation of EMG activation as a % of the participant's MVC (Burden et al., 2003). With the exhibited reliability (intra-class correlation coefficient [ICC] = 0.952, 95% confidence interval [CI] = 0.610-0.999), the first MVC was used to normalize EMG values. This satisfactory level of MVC reliability allowed the first MVC performed to be used to normalize EMG values. The dependent variables explored were the loads lifted and the EMG activity during the squat actions, with the independent variables being the three different squat conditions utilised.

Statistical Procedures

All data were considered to be normally distributed, as the Shapiro-Wilks test for normality was found to have an alpha level of $p > 0.05$. Main effects were examined with a two (dominant and non-dominant erector spinae activity) x three (squat conditions) repeated measures ANOVA. A one-way repeated measures ANOVA explored differences in the 1-RM loads lifted for each squat condition. Following the ANOVAs, a pairwise comparison post-hoc test was performed (Bonferroni) to explore differences between individual variables. Effect size was calculated using partial eta-squared (η^2). Statistical analysis was performed using SPSS version 17 for Windows (SPSS Inc, Chicago, IL, USA) with the alpha level set at $p \leq 0.05$. Reliability of the EMG measures was assessed using ICC and 95% CI to compare repeated test measures. Reliability was calculated as ICC = 0.87 (95% CI = 0.724-0.966) for the Smith Machine squat, ICC = 0.85 (95% CI = 0.68-0.941) for the barbell squat condition and ICC = 0.80 (95% CI = 0.56-0.929) within the destabilizing bar squat.

Results

Table 1 about here

When the mass lifted for the 1-RM attempt for each squat condition was explored (Table 1), a significant main effect was noted ($F = 6.952$, $p = 0.01$, $\eta^2 = 0.537$; large effect size [Olejnik & Algina, 2003]). Pairwise comparisons indicated that the Smith Machine squat load was significantly ($p = 0.006$, 95% CI = 4.376 – 25.766) higher than the barbell squat (10.9%), with a marginal increase (2.5%) compared to the destabilizing bar squat, found to be non-significant (p = 1.000). The destabilizing bar squat load was greater than the barbell squat load (8.7%), but was found to be non-significant (p = 0.100).

When the normalized EMG values for the dominant and non-dominant erector spinae were combined, a significant main effect was found when squat types were compared (F = 5.852, p = 0.017, η^2 = 0.517; large effect size). Pairwise comparisons indicated that the destabilizing bar squat was linked to significantly greater EMG activity compared to the Smith Machine squat (p = 0.011, 95% CI = 7.422 – 58.654) and the barbell squat (p = 0.022, 95% CI = 2.130 – 30.111). The barbell squat also produced a significantly greater EMG value compared to the Smith Machine squat (p = 0.036, 95% CI = 1.020 – 32.815).

When the EMG values were explored in greater depth, to investigate differences between the dominant and non-dominant sides (Table 1), a greater mean EMG value was recorded for the non-dominant side in all squat conditions, with the destabilizing bar squat showing the largest difference (14.5%). However, none of these patterns was found to be significant (p > 0.05).

Discussion and Implications

The results from the present study indicate a significant increase in the load lifted in the Smith Machine squat compared to the barbell squat. This pattern of response was expected and is supported by Cotterman et al. (2005) who also found a significant decrease in 1-RM load in barbell squats compared to Smith Machine squats. The decrease in maximal load in the barbell intervention is likely to be due to the barbell squat offering instability in three planes of motion, thereby forcing the lifter to produce force in all three planes (Schick et al., 2010). The Smith Machine squat, although a similar movement, is considered to be an easier action as the barbell is stabilised in two parallel tracks. This allows greater attention to force production by prime movers, as the mass being lifted is largely being stabilized by the Smith Machine itself, rather than the athlete (Schick et al., 2010).

The results of this study confirm that the Smith Machine squat offers lifters the opportunity to overcome heavier loads. However, there is a potential problem with regard to the transfer of this force to more dynamic sporting/exercise situations. Schick et al. (2010) consider the barbell squat to be a superior exercise compared to the Smith Machine squat, as the muscles contract in a more natural fashion, ensuring balance in three planes of motion. Barbell actions cause a higher demand on the lifter to stabilize the load and control the movement while overcoming the chosen resistance (Langford et al., 2007). This increases the stress on the lifter to coordinate the activity of more synergist, fixator and antagonistic muscle groups (Behm, & Colado, 2012). Consequently, the transfer of strength gains to more unstable conditions (e.g. sports and exercise) is increased to a greater extent than through Smith Machine actions (Langford et al., 2007).

If Langford et al. (2007) are correct, in terms of the transfer of a training stimulus to sports actions being greater when the load lifted needs to be stabilised, then the results of the destabilizing bar squat within the present study could be of particular interest to coaches and athletes. The loads lifted in this condition were only marginally less than in the Smith Machine condition, while there was an average increase in the load of 11.7 kg compared to the barbell squat. It should be remembered that past research which has induced instability at the foot/ground interface has found a significant decrease in force production in the unstable condition (Behm, Anderson, & Curnew, 2002, McBride, Cormie, & Dean, 2006, McBride et al., 2010). Shifting the instability focus to the athlete's torso could better replicate more random sports situations, where coordination and muscle synergy are vital, without involving a decrease in the load being lifted. Interestingly, although the increase in destabilizing bar compared to bar bell load was not statistically significant, future research may warrant a more in-depth look at maximal loads lifted in these squat conditions. This is particularly pertinent as the subjects used within this study were all experienced in barbell and Smith Machine squat actions, but had not used the Tendo Bar system in their training. Thus, the possibility that the destabilizing bar squat load could increase with greater familiarisation is plausible, particularly in light of Cotterman et al. (2005) finding that lifters experienced in Smith Machine and barbell squats showed no difference in performance, while inexperienced lifters could lift greater loads in the more stable (Smith Machine) squat condition.

The destabilizing bar squat was classified as the least stable condition examined. The subjects commented on this, in terms of the difficulty they experienced in controlling the load during lifts (it was noted visually that torso perturbations were substantially greater in the destabilizing bar squat than in the other test conditions). However, this stability challenge did not decrease the 1-RM lifted and there seem to be two possible explanations for this. Firstly, the Tendo system positioned part of the load (37 kg) below the barbell, decreasing the height of the lifter and the loads combined centre of gravity compared to either the Smith Machine or barbell squat conditions, (where the mass lifted is held at the level of the shoulder girdle). This could increase the global stability felt at the foot/ground interface, due to the fact that a lower centre of gravity is linked to greater human stability (Hall, 2003). This could offset the local stability issues experienced by subjects around the torso and shoulder girdle, allowing increases in the load being lifted compared to the barbell squat. This was commented on by subjects who felt that their balance at ground contact was unaffected by the Tendo device, while their torso stability was greatly challenged.

A second possible theory is linked to the Tendo device being set on springs. This causes a decrease in bar stability, as the load attached to the bar ‘bounces’ thus making it harder to stabilize the mass lifted as the torso attempts to dampen the oscillations it is experiencing. However, the system’s springs may also stretch in the descent phase of the squat, storing strain energy. The strain energy is subsequently utilised in the upward phase, as the springs return to their resting length, thus helping the lifter overcome a greater load than would normally be lifted. At present this is only a supposition, but could be worthy of further investigation as this type of device becomes a more popular method of training athletes.

The EMG results from the present study indicate that as the stability of the squat exercise decreases, the erector spinae longissimus muscle activity increases. The destabilizing bar EMG activity was significantly higher than in the other squat conditions, with the barbell

EMG significantly higher than the Smith Machine activation. The Smith Machine squat EMG activity was lower than in the other actions studied, due to the Smith Machine providing stability in two planes, thus requiring the postural muscles to work less to maintain a neutral torso. However, the differences between the barbell and destabilizing bar conditions are less clear. The destabilizing bar system positions part of the load below the bar, thus decreasing the centre of gravity of the load lifted and causing less torque to be applied to the torso when compared to the barbell squat, where the entire load is positioned on the shoulders. Theoretically, this would cause a greater need to stabilise the torso in the barbell action and therefore a greater need to recruit torso musculature compared to the destabilizing bar action. However, this was not found in the present study, with EMG activity greatest in the destabilizing bar squat. It could be that the backward and forward movement and the oscillating process produced by the destabilizing bar spring system generate a greater stability challenge to the trunk musculature, by making it harder to balance the load being lifted. This seems to cause greater motor unit recruitment of the back muscles to keep an upright neutral posture and maintain spinal stability through the lift, regardless of the load's centre of gravity and its effect on torque.

Past literature has shown different patterns of response with regard to trunk muscle activation compared to the present study's findings. Anderson and Behm (2005) found increased erector spinae activity when a barbell squat was performed on two balance discs compared to a Smith Machine or normal barbell squat. However, normal barbell squat produced no greater EMG activity of the lumbo-sacral erector spinae or abdominal stabilisers compared to the Smith Machine action. Schwanbeck et al. (2009) also found no difference in activation of the erector spinae and rectus abdominus when Smith Machine and barbell squats were compared. Interestingly, erector spinae activity was higher than rectus abdominus activity in both squats, highlighting the importance of the erector spinae muscle recruitment in trunk stabilisation while squatting. However, it must be acknowledged that this previous research is fundamentally different to the present study. Anderson and Behm (2005) lifted the same sub-maximal load for the Smith Machine and barbell squat, which is a potential problem, given that the present study's findings showed a significantly greater load lifted in the Smith Machine condition. Schwanbeck et al. (2009) used 8-RM as their experimental load rather than an exercise intensity designed to develop strength (≥ 85%), as the present study utilised. Therefore, the maximal loads used to develop strength have not been explored in terms of trunk activation until now. The present study aimed to produce instability in a more functional fashion, with a stable surface used for all squats and instability being generated by the lifting modality adopted (Kohler et al., 2010). It may be argued that this may have more transfer and greater benefits for athletes' training regimes than either lifting very stable loads, or lifting on unstable platforms.

Interestingly, non-dominant erector spinae activity was higher in each squat condition when compared to the dominant side, with the destabilizing bar squat producing larger differences between the dominant/non-dominant sides. It is acknowledged that this is a tentative conclusion as statistical significance was not met, (probably due to the large standard deviation found in the EMG data set), but it does warrant further investigation, especially considering evidence exists to show that muscle imbalances are linked to decreases in performance (Young, et al., 2002) and an increased likelihood of injury (Orchard, et al., 1997). In particular, it would be interesting to investigate if muscle imbalances can be alleviated if a stability challenge is added to a squat exercise.

Conclusion

The aim of this study was to identify how changes in the stability conditions applied to a barbell during a back squat affect maximal load lifted and erector spinae muscle activity. This was achieved by examining squats with different stability challenges. Smith Machine (most stable), barbell and destabilizing bar (least stable) squats 1-RM loads and EMG activity while lifting 85% of 1-RM were compared. The study found a significant increase in erector spinae EMG activity linked to a decrease in squat stability. When load lifted was recorded, though the Smith Machine squat was significantly greater than the barbell squat, no difference between the destabilizing bar and Smith Machine squat was found.

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Tables

Table 1. Summary of Erector Spinae EMG Activity and Maximal Loads Lifted (n=14).

Squat	Dominant Side (% MVC)	Non Dominant Side (% MVC)	1-RM Load (kg)
Smith Machine	91.8 ± 35.9	95.7 ± 39.1	138.5 ± 35.0
Barbell	107.8 ± 38.1	113.5 ± 37.1*	123.5 ± 35.5*
Destabilizing Bar	119.5 ± 39.5*[§]	134.1 ± 55.4*[§]	135.0 ± 38.0

* Significantly different from the Smith Machine squat condition ($p \leq 0.05$). [§] Significantly different from the barbell squat condition ($p \leq 0.05$).

Figure Captions

Figure 1. Tendo-Destabilising Bar System: posterior view (A) and lateral view (B).